OVPR Seed Grant: A Smart Artificial Pancreas for Patients with Diabetes

Overview:

People with type-1 and insulin-dependent type-2 diabetes rely on external insulin to control their blood glucose (BG) levels so that they remain inside a normal euglycemic range. Researchers have accumulated extensive knowledge on how to design closed-loop insulin control to treat diabetes. This research provides a solid scientific foundation for artificial pancreas (AP) systems, and enables their successful deployment on real patients. Existing AP systems, however, have extremely limited information about various physical activities and physiological states that influences the patient's glucose levels. Moreover, our real patient data shows that simply using a unified algorithm, with variations in a few parameters to account for physiological variations across individuals, is not effective and can actually be harmful to the patient in certain cases.

To address this state of affairs, this project seeks to i) develop new technology for collecting behavioral and physiological data that reflects the patient state in a more timely and accurate manner; ii) design Machine Learning-based personalized insulin therapy that can deal with unexpected upswings and downswings in BG caused by patient specific conditions using real-time data available from connected devices and sensors; iii) develop a decision support system to provide just-in-time alert for patients to take preventive interventions; iv) build an open testbed that can evaluate proposed solutions using extensive heterogeneous patient datasets.

Intellectual Merits:

Our key intellectual merit is the development of a **data-driven, smart closed-loop control framework** for the artificial pancreas, consisting of four major components:

- New sensing techniques that can detect behavioral and physiological factors that, directly and indirectly, influence patient blood-glucose levels.
- Imitation Learning-based controller design that can generalize from limited training data to cope with unexpected complex dynamics.
- Reinforcement Learning-based online control design that is adaptive to long-term emerging patient-specific conditions.
- Clinical decision support to provide just-in-time, patient-specific intervention that reduces safety risks.

Our proposed research will be conducted by experts in both closed-loop control and in clinical diabetes treatment and care. Critically, we have access to large datasets of artificial-pancreas patients, spanning a period of 12 months. This will allow us to better understand the clinical needs of patients and doctors.

Broader Impacts:

1) Type-1 and type-2 diabetes affect tens of millions of people in the US alone (10.5% of the population), including nearly 200,000 children who must rely on externally administered insulin to control their BG levels. The cost of diabetes in 2017 was $327 billion. The proposed work seeks to develop personalized control algorithms for the AP that can improve these patients' clinical outcomes. 2) The design of the artificial pancreas is a prototypical problem involving numerous challenges in deploying machine-learning methods safely in the medical domain. The emphasis on providing safety assurances for systems with neural networks, and on using careful modeling of uncertainties in our patient models, will help guide the community toward a safe and well-considered deployment of these approaches. 3) Technologies developed in this project will be translated to clinical studies for real patient evaluation. We shall seek funding from agencies such as NIH and JDRF to support such studies. 4) The proposed research includes training and technology dissemination for health science and engineering students; new materials will be included in the curriculum of ESE 534, Cyber-Physical Systems. 5) Outreach to patients: working with the Stony Brook Diabetes Center will allow us to hold a workshop and consultation sessions with artificial-pancreas patients.